Functional Diversity at Landscape Scale using Sentinel-2 imagery

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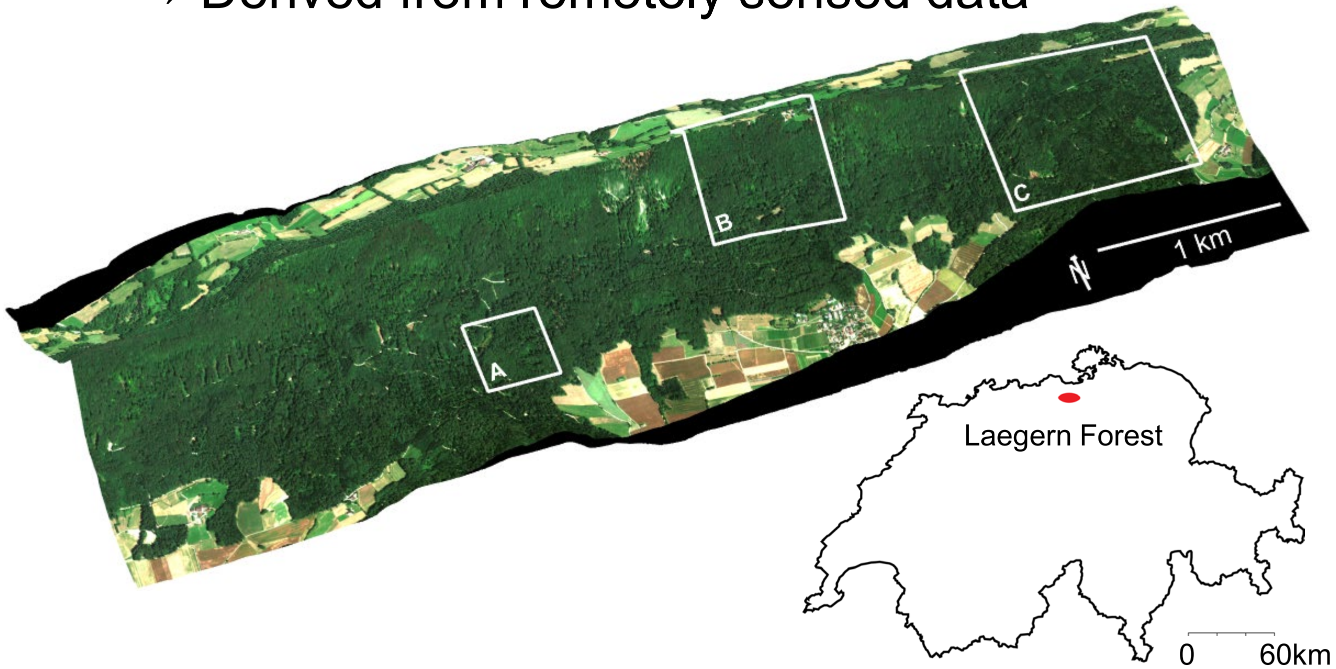
Measuring functional diversity using remote sensing

- Functional diversity

→ Measuring diversity using functional traits

→ Morphological, physiological and phenological traits

→ Derived from remotely sensed data



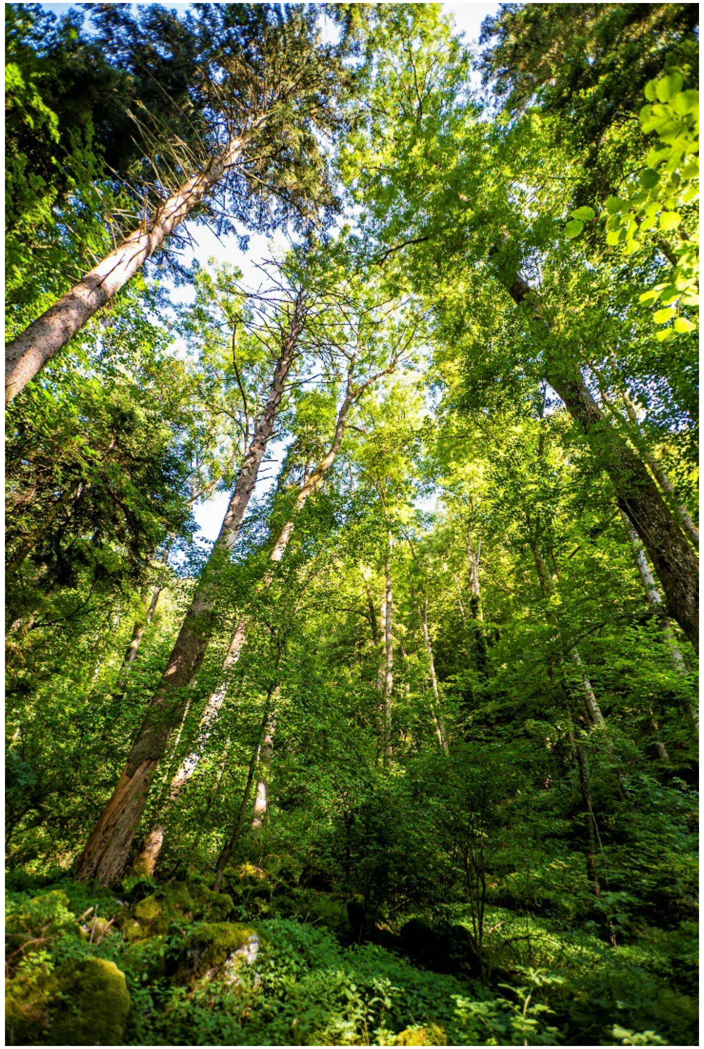
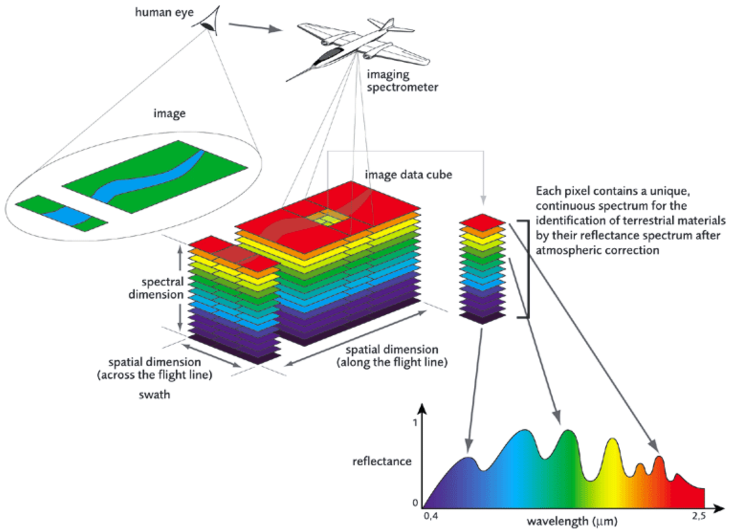


Image: F.D. Schneider

Homolová, Lucie (2014). "Imaging spectroscopy for ecological analysis in forest and grassland ecosystems." Wageningen University..
Violle, Cyrille et al. (2007). "Let the concept of trait be functional!" In: Oikos 116, pp. 882–892. ISSN:18825176. DOI: doi:10.1111/j.2007.0030-1299.15559.x.

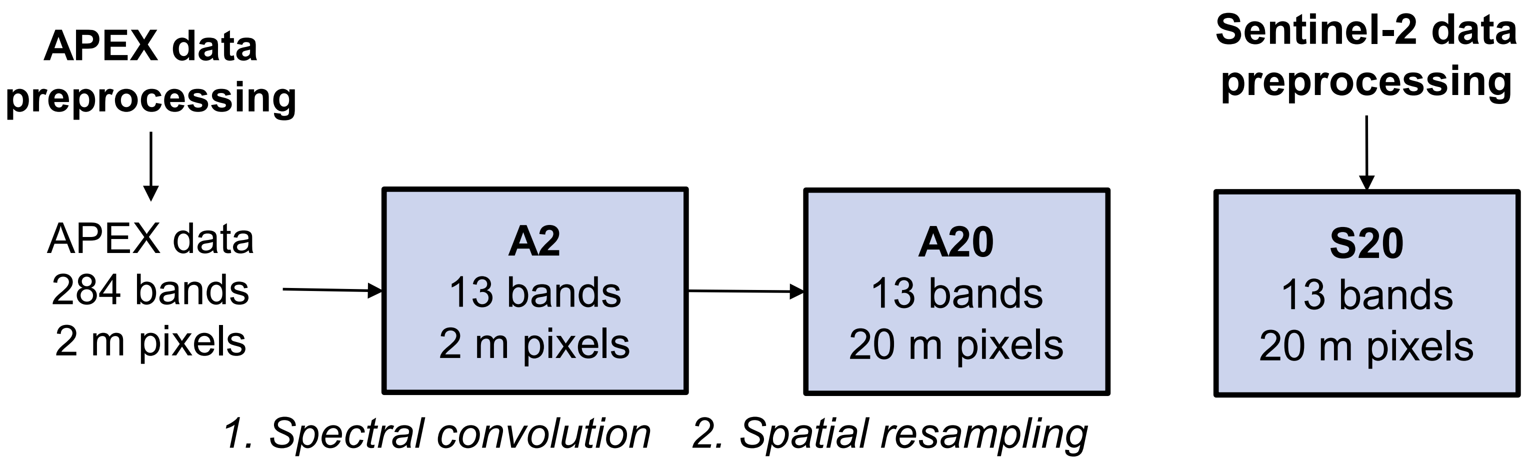
Airborne and spaceborne systems

Sensor	Airborne Prism Experiment APEX	ESA's Sentinel-2A and 2B
Temporal resolution	2 – 6 campaigns per year	repeat cycle: 10 days with one satellite and 5 days with 2 satellites
Spatial resolution	2 m pixel size	10 m, 20 m and 60 m pixel size
Spectral resolution	284 spectral bands	13 spectral bands

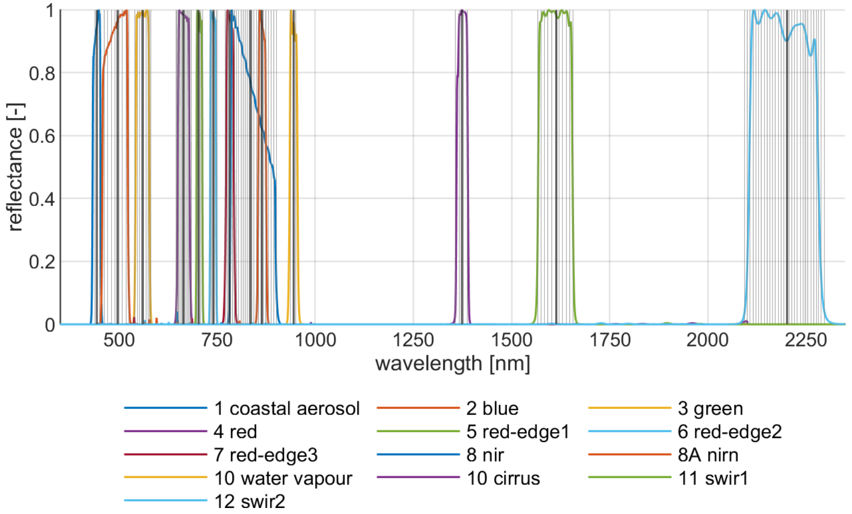


ESA (2017) "Sentinel-2 MSI". Available at: https://earth.esa.int/web/sentinel/user-guides/sentinel-2-msi (Accessed: 21 May 2017).
Schaepman, M. E. et al. (2015) "Advanced radiometry measurements and Earth science applications with the Airborne Prism Experiment (APEX)", Remote Sensing of Environment, 158, pp. 207–219. DOI: 10.1016/j.rse.2014.11.014.
Images: http://www.apex-esa.org/content/imaging-spectroscopy/, https://de.wikipedia.org/wiki/Sentinel-2#/media/File:Sentinel_2-IMG_5873-white.jpg

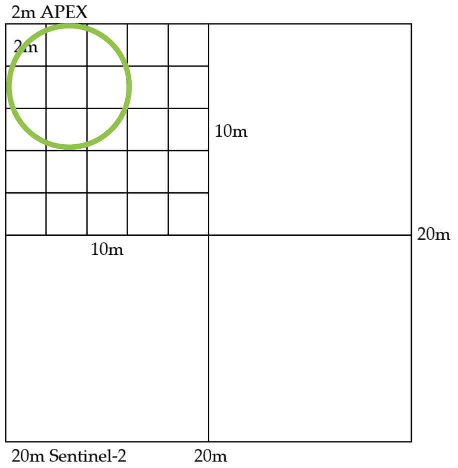
Scaling functional diversity to Sentinel-2



Spectral Resolution



Spatial Resolution



Helfenstein, I.S., Schneider, F.D., Schaepman, M.E. & Morsdorf, F. (2022): Assessing biodiversity from space: Impact of spatial and spectral resolution on trait-based functional diversity. Remote Sens. Environ. 275, 113024.

Spectral indices as proxies for physiological traits

- 18 spectral indices as proxies for **chlorophyll content**, **canopy water content**, **red pigments** (anthocyanin content, carotenoid content, carotenoid/chlorophyll ratio)

Conditions:

1. supported by the spectral resolution of the Sentinel-2 MSI sensor
2. high correlation when linked to the same trait, but not between traits
3. high correlation between datasets A20 and S20
4. suitable at different spatial scales

Results:

Chlorophyll: **CIre**, NDRE2, Cig

Red pigments: **CCI**, PSRI

Water content: **NDWI**, NDII

A20 \ S20	CIre	CIg	MTCI	NDRE1	NDRE2	REP	M_{OSAVI}	T_{OSAVI}	ARI1	ARI2	CRI1	CRI2	CCI	PSRI	NDMI	NDWI	NDII	MSI	A20/S20
CIre	1	0.81	0.794	0.91	0.989	0.466	0.001	0.214	0.009	0.311	0.034	0.03	0.183	0.174	0.074	0.296	0.279	0.283	0.765
CIg	0.829	1	0.469	0.737	0.794	0.303	0.085	0.126	0.057	0.539	0.089	0.093	0.181	0.308	0.006	0.135	0.123	0.126	0.668
MTCI	0.394	0.442	1	0.829	0.789	0.293	0.075	0.281	0.003	0.087	0.002	0.003	0.034	0.225	0.08	0.224	0.228	0.231	0.63
NDRE1	0.662	0.695	0.644	1	0.918	0.211	0.006	0.199	0.007	0.356	0.06	0.045	0.258	0.142	0.071	0.295	0.305	0.312	0.719
NDRE2	0.998	0.821	0.393	0.668	1	0.471	0	0.233	0.012	0.302	0.039	0.035	0.187	0.168	0.072	0.298	0.278	0.284	0.761
REP	0.398	0.199	0.002	0.005	0.392	1	0.094	0.187	0.014	0.008	0.006	0	0.003	0.142	0.031	0.099	0.056	0.057	0.566
M_{OSAVI}	0.261	0.355	0.567	0.734	0.258	0.07	1	0.363	0.104	0.478	0.019	0	0.428	0.053	0	0.013	0.025	0.026	0.562
T_{OSAVI}	0.634	0.669	0.077	0.379	0.636	0.276	0.057	1	0.592	0.002	0.231	0.387	0.007	0.14	0.002	0.013	0.002	0.002	0.545
ARI1	0.134	0.125	0.082	0	0.137	0.357	0.181	0.55	1	0	0.384	0.647	0.038	0.176	0.128	0.06	0.127	0.128	0.285
ARI2	0.343	0.245	0	0.247	0.338	0.089	0.139	0.304	0.096	1	0.289	0.161	0.47	0.02	0.001	0.079	0.136	0.139	0.197
CRI1	0.051	0.008	0.284	0.002	0.052	0.158	0.087	0.231	0.49	0.534	1	0.93	0.155	0	0.028	0	0	0	-0.286
CRI2	0.086	0.037	0.234	0.001	0.088	0.25	0.133	0.373	0.74	0.4	0.933	1	0.054	0.017	0.061	0.005	0.015	0.015	-0.199
CCI	0.233	0.118	0.189	0.567	0.237	0.036	0.538	0.094	0.036	0.336	0.026	0.002	1	0.219	0.099	0.292	0.328	0.334	0.853
PSRI	0.074	0.275	0.046	0.004	0.071	0.158	0.005	0.141	0.146	0.022	0.026	0.001	0.347	1	0.076	0.04	0.051	0.051	0.725
NDMI	0.057	0.021	0.068	0	0.056	0.14	0	0.022	0.025	0.346	0.241	0.166	0.004	0	1	0.788	0.666	0.66	0.124
NDWI	0.35	0.145	0.117	0.248	0.35	0.122	0.088	0.2	0.047	0.187	0.096	0.089	0.326	0.07	0.017	1	0.853	0.851	0.832
NDII	0.345	0.149	0.153	0.279	0.346	0.092	0.118	0.183	0.028	0.162	0.065	0.058	0.357	0.076	0.028	0.994	1	0.999	0.784
MSI	0.354	0.153	0.16	0.289	0.356	0.094	0.122	0.185	0.027	0.165	0.064	0.057	0.366	0.077	0.025	0.991	0.998	1	0.783

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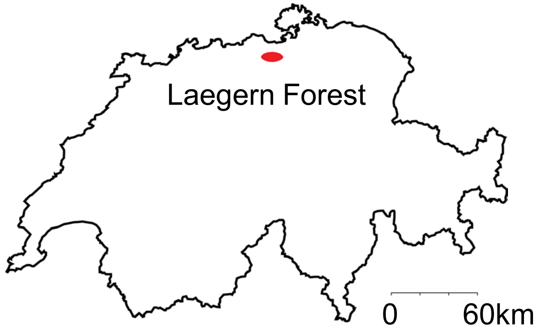
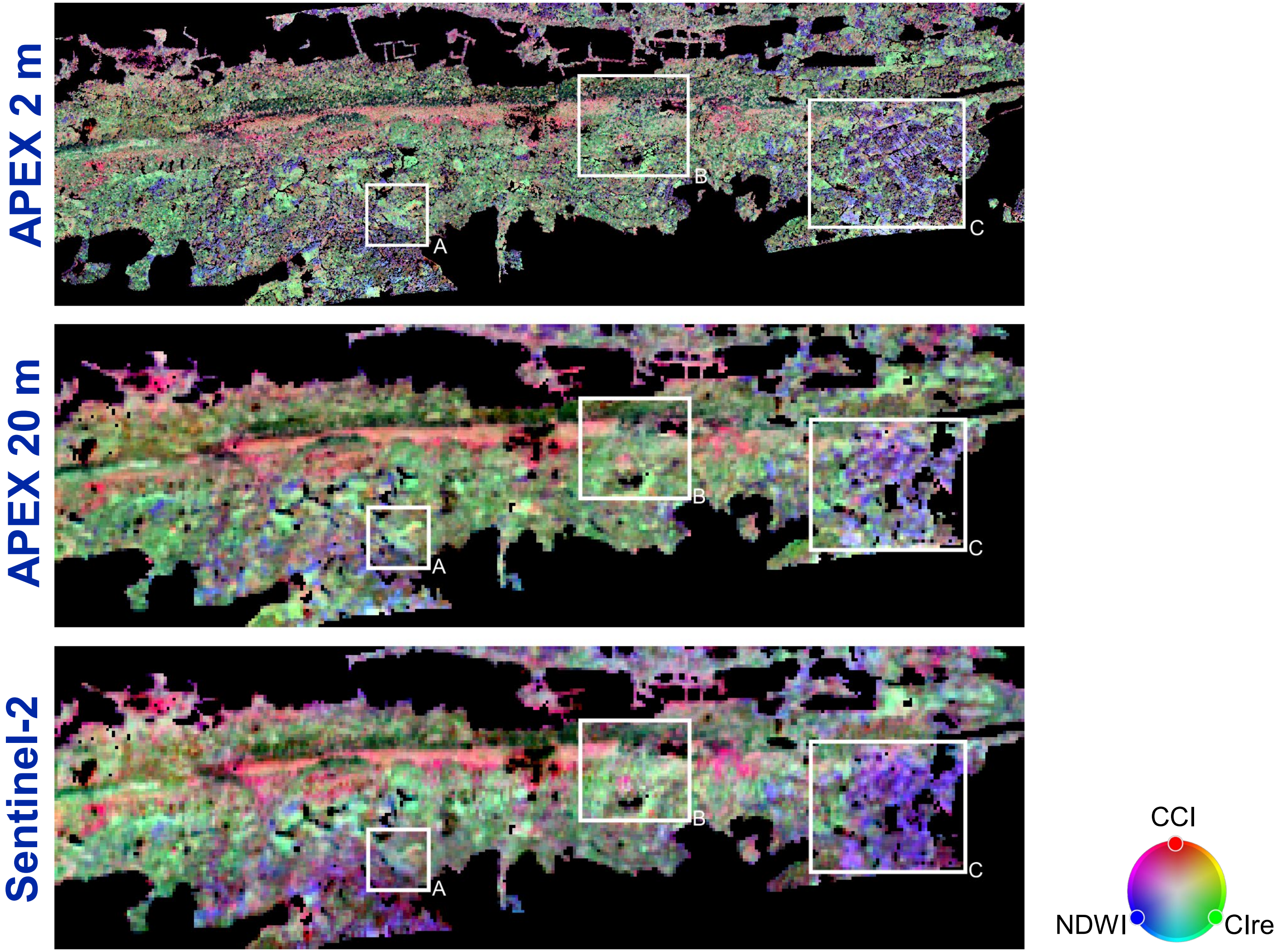
Physiological trait maps





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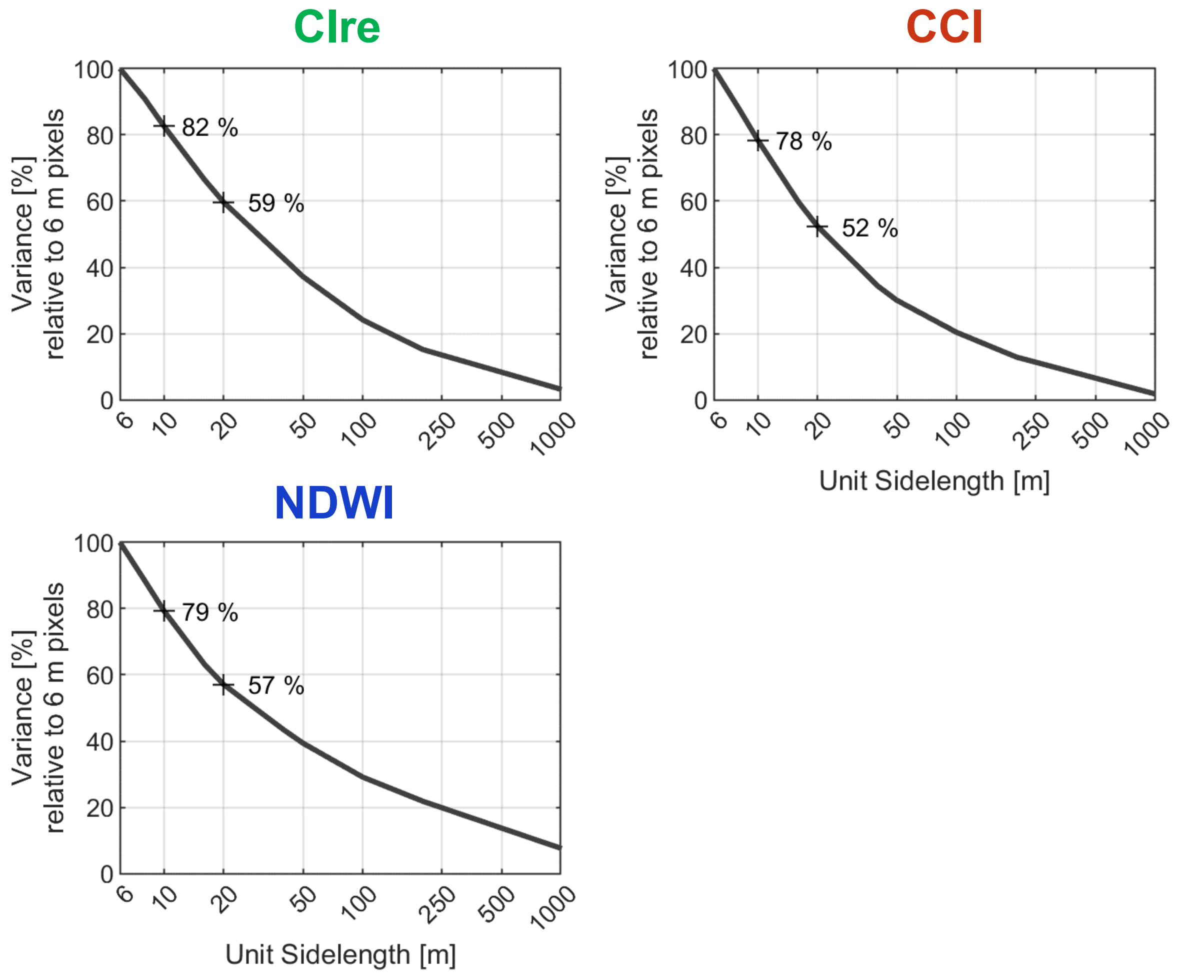
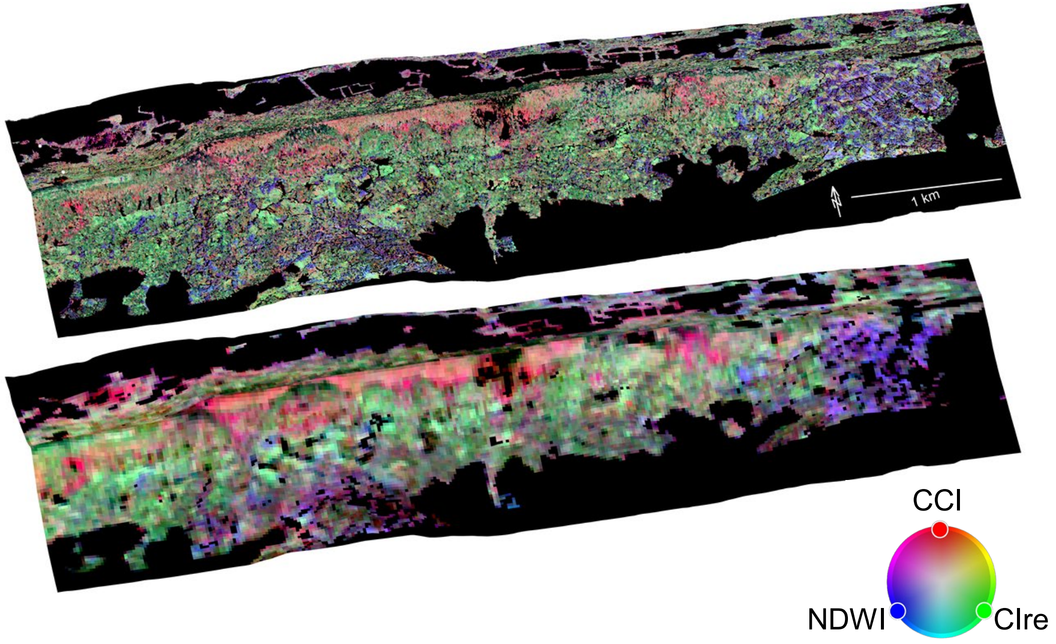
Impact of spatial resolution on variance of physiological traits





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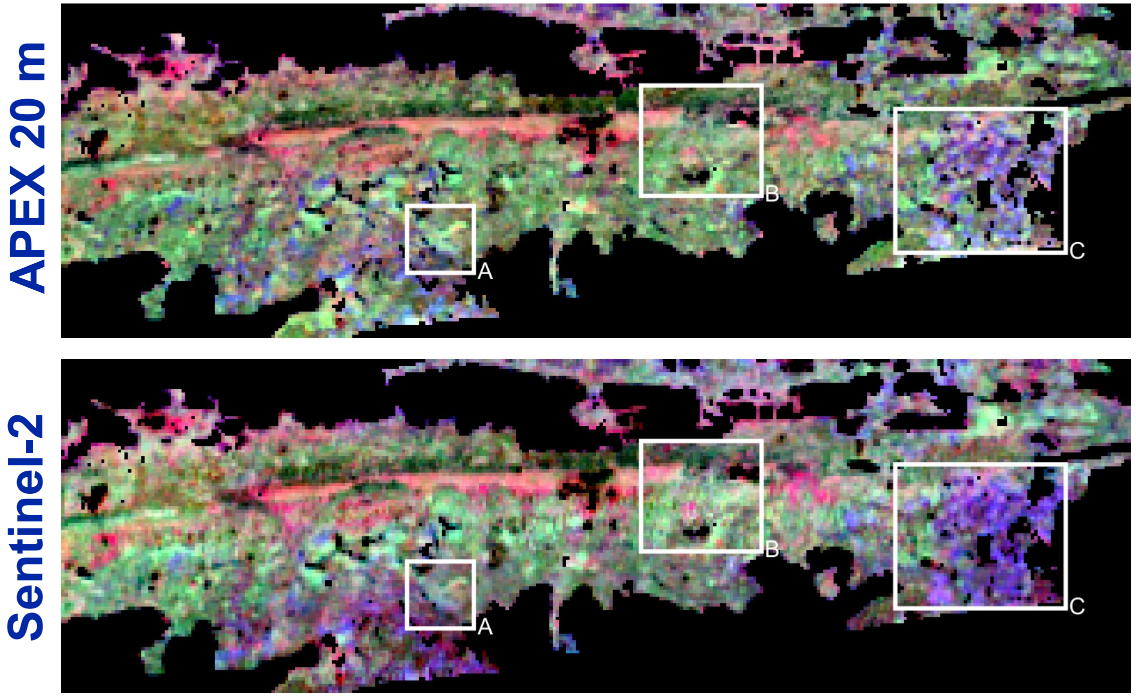
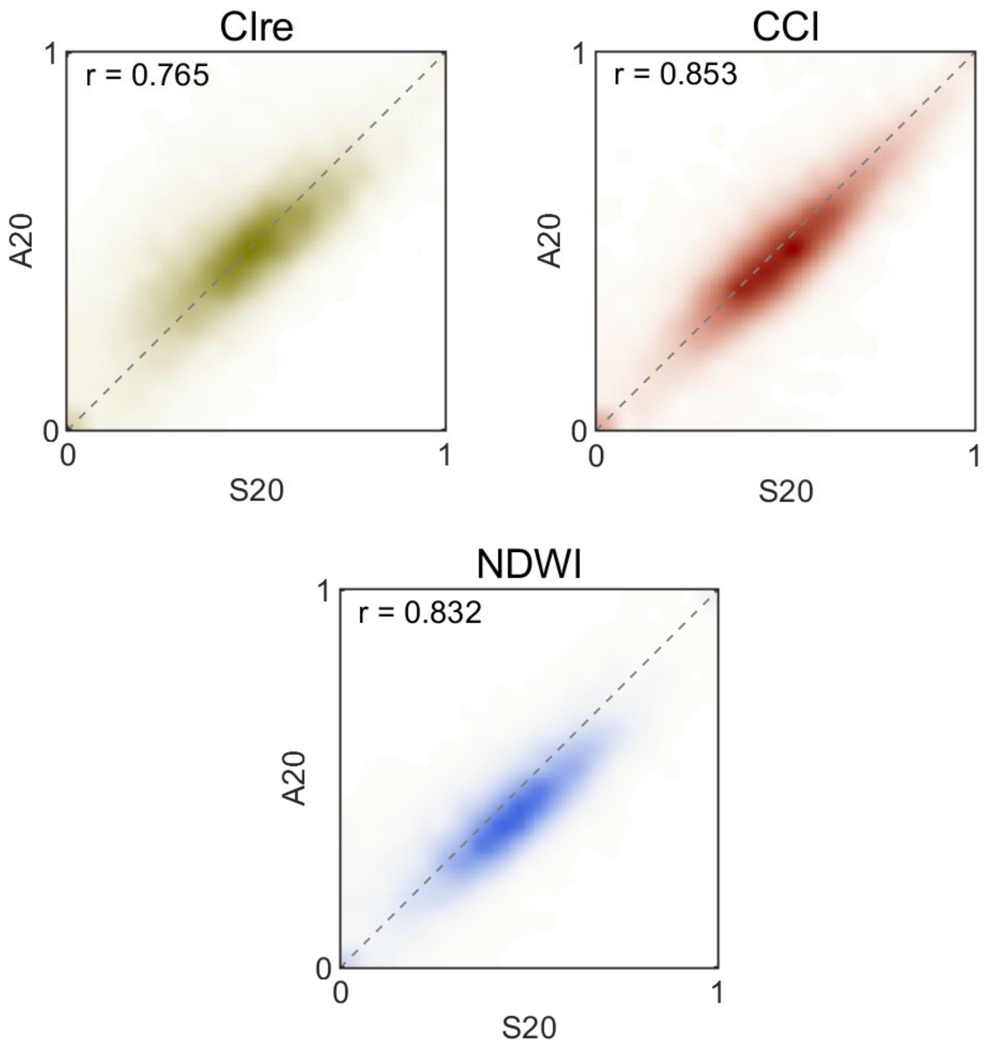
Impact of sensors on physiological traits





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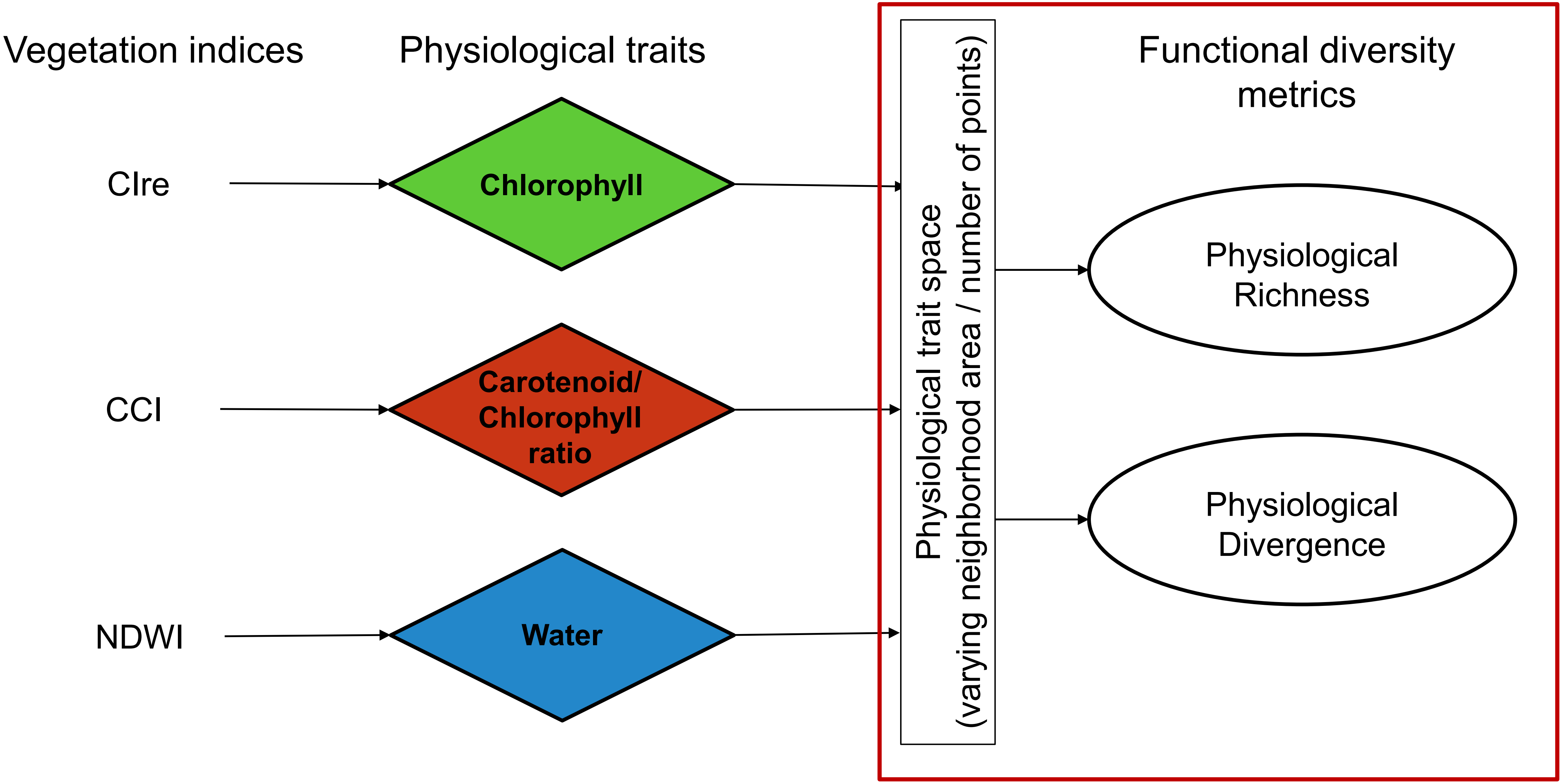
Measuring functional diversity using Remote Sensing



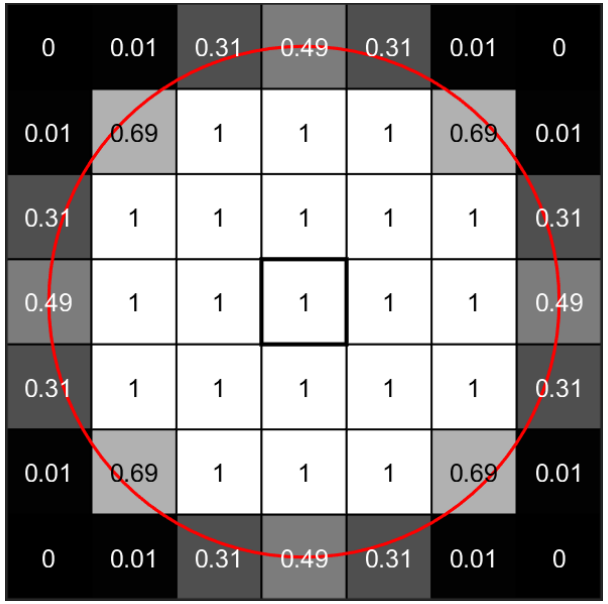
Functional diversity metrics

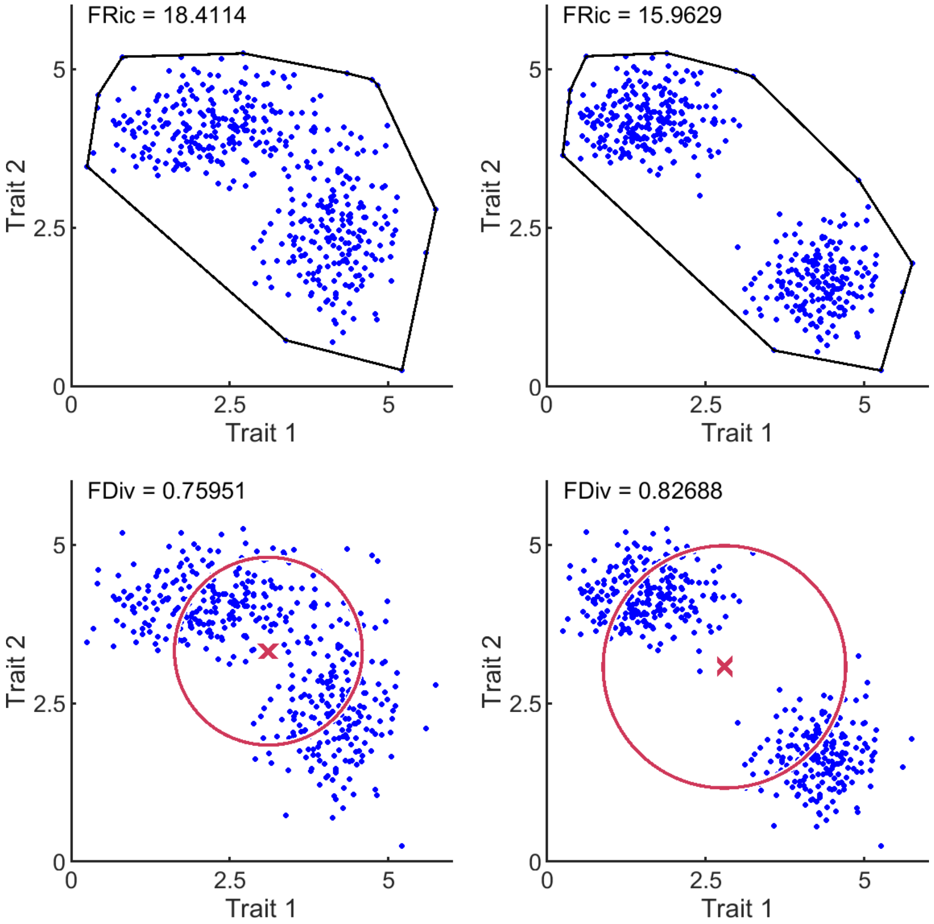
- Functional Richness
  = measure of extent

  → How many different value are present?

- Functional Divergence
  = measure of distribution

  → How are the different values organized?





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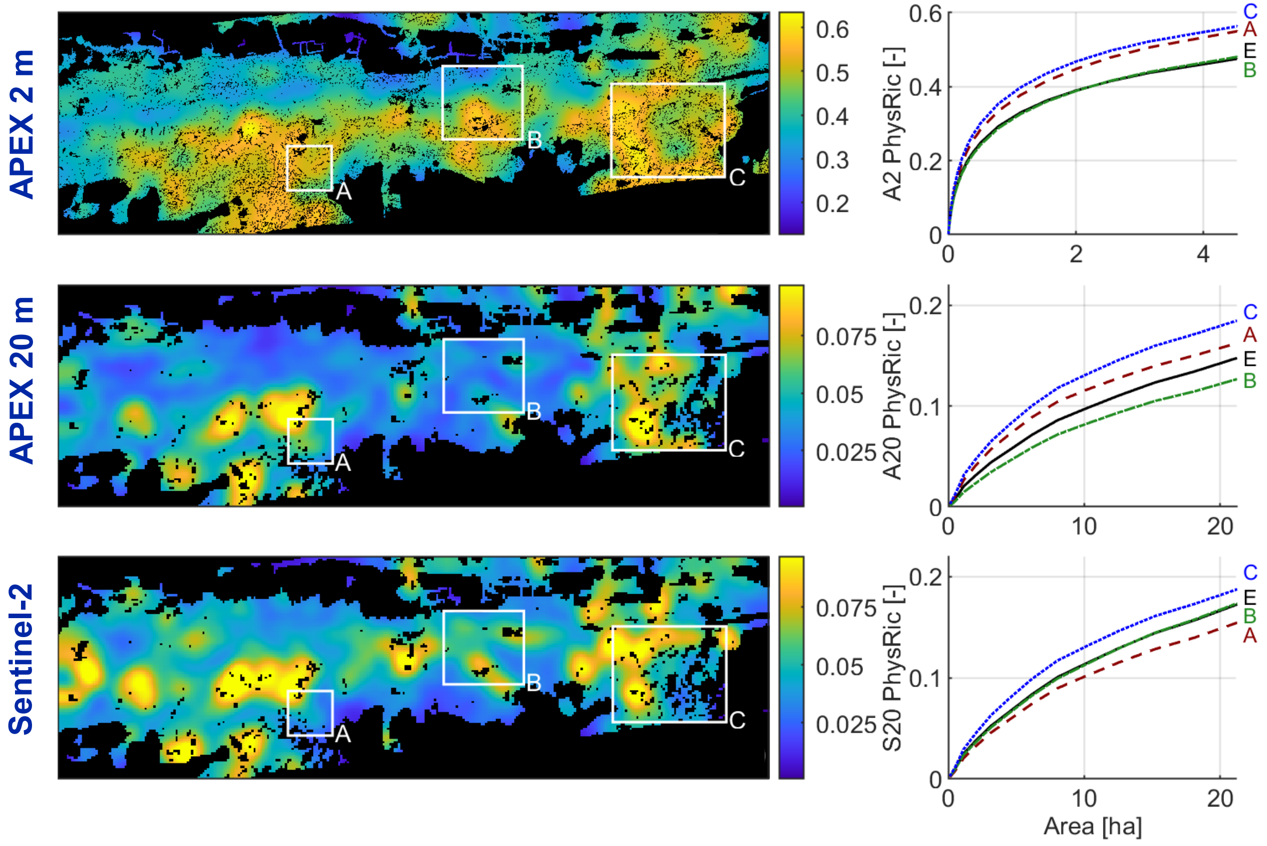
Physiological diversity maps

- New value range
- Interpretation of large scale patterns
- Interpretations of results: increase around ‘hotspots’
- Mixed-pixels around forest edge and gaps
  → Increase in functional richness
- Richness-area relationships change with pixel size

Physiological Richness



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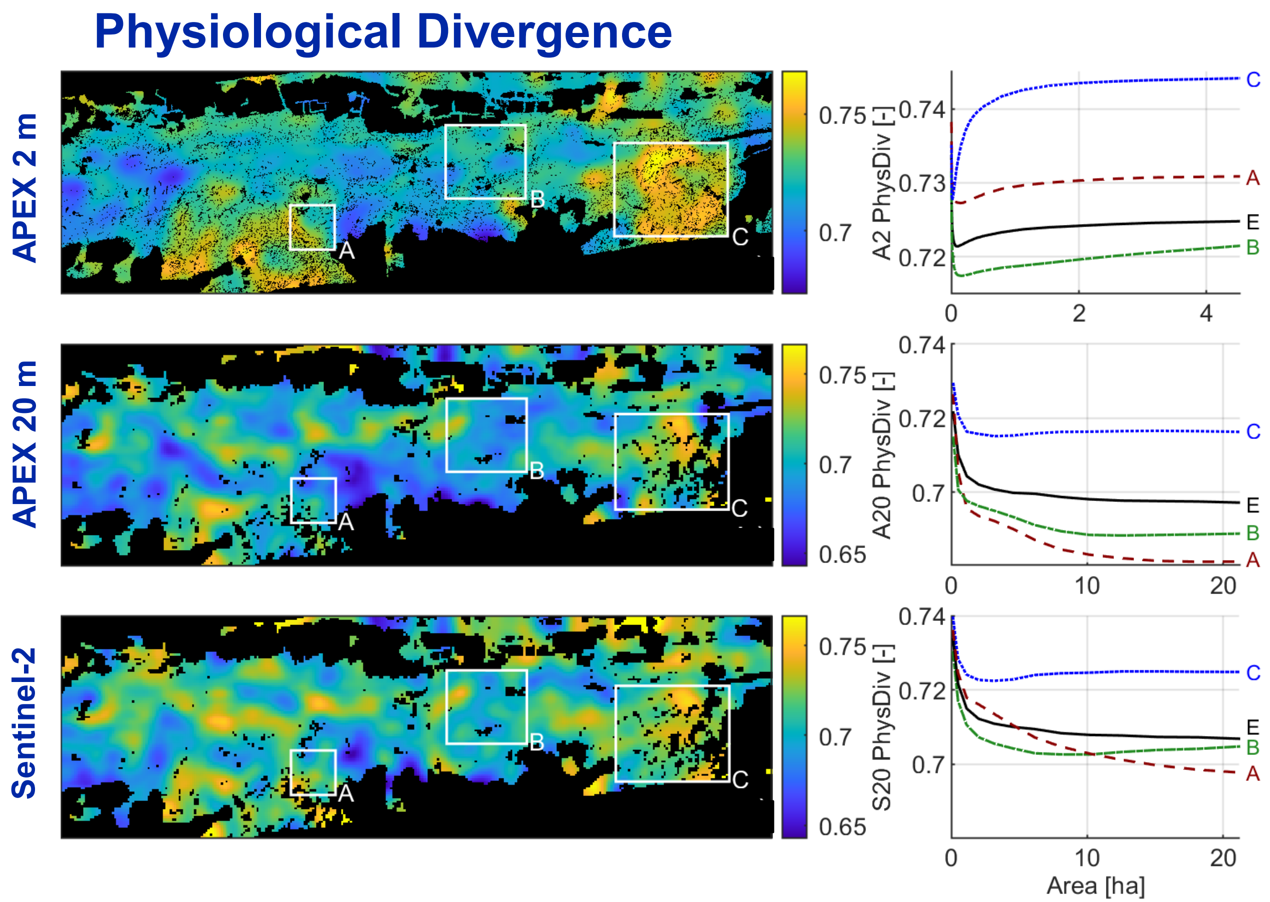
Physiological diversity maps

- Values comparable through scale
- Interpretation of large scale patterns: increase of functional divergence at transition of communities
- Mixed-pixels around forest and gaps
  → Decrease in functional divergence
- Stabilization of divergence at > 3 pixel radius
  → Minimum calculation area



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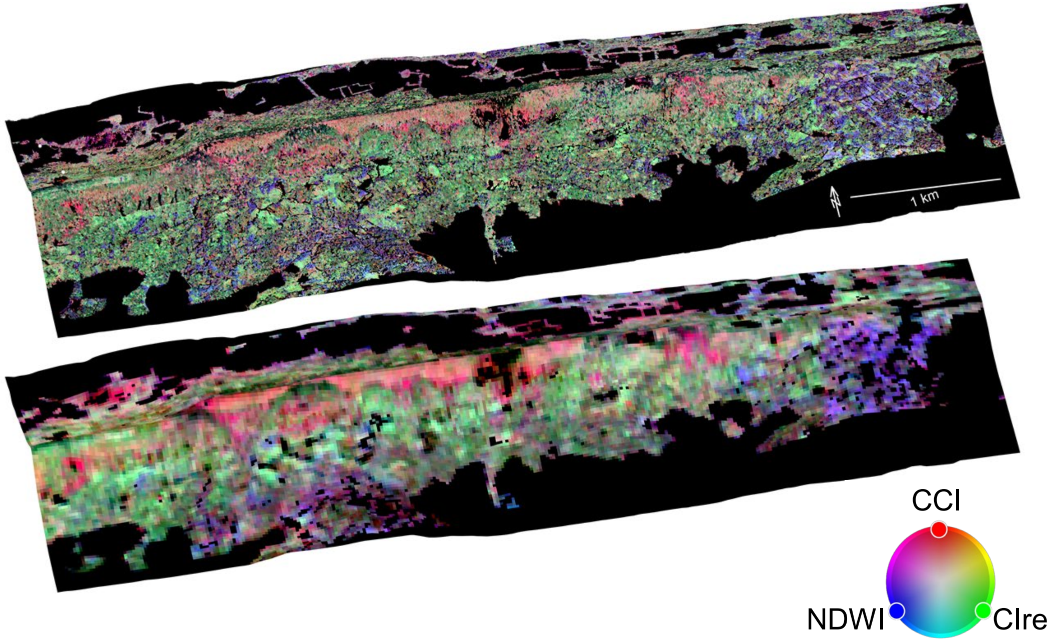
Functional Diversity using Sentinel-2 imagery

- Observing functional diversity continuously in time and space using satellite imagery
- Functional diversity metrics depend on the size and number of pixels
- Minimum calculation area with 60 m radius or 1.1 ha recommended
- Importance of spatial and spectral resolution when scaling diversity assessments to landscape scales
- Promising applications at landscape scales

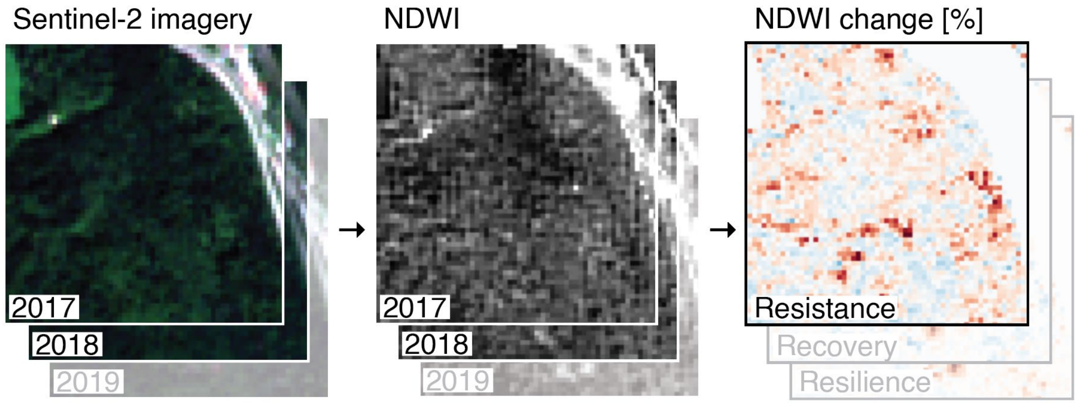


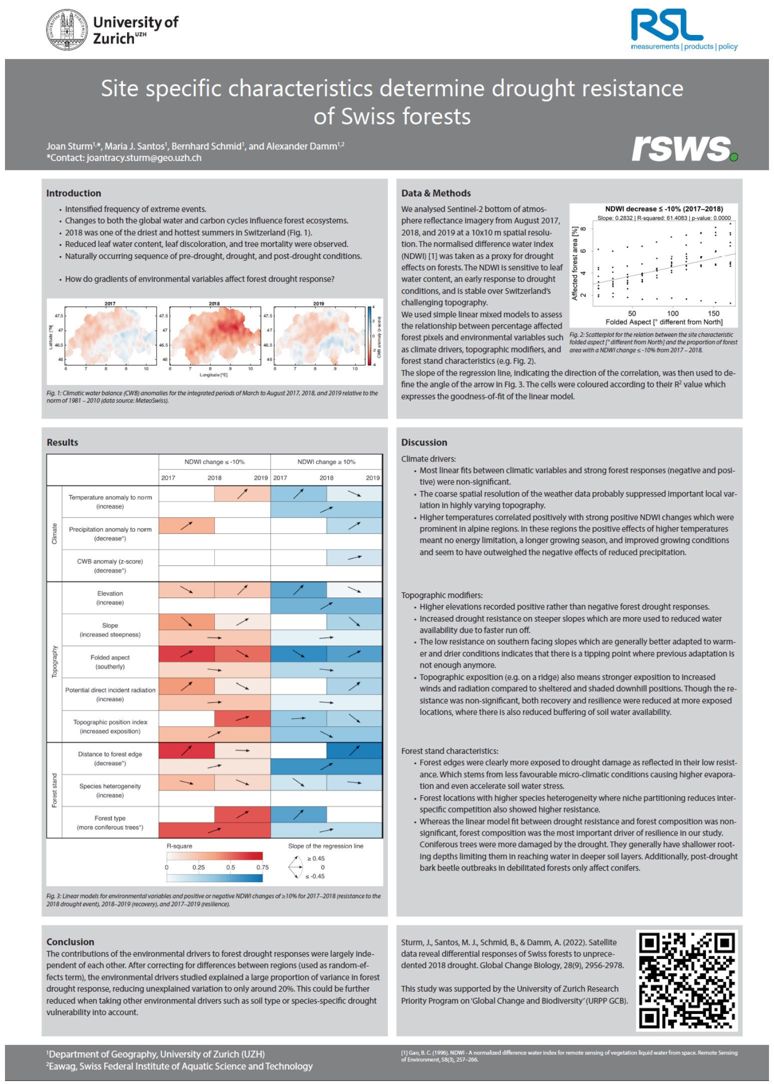
Poster

A2.03 Ecosystem Resilience

Topography and stand characteristics controlled forest response to the 2018 drought in Switzerland

Sturm, J., Santos, M.J., Schmid, B., Damm, A.





Sturm, J.T., Santos, M.J., Schmid, B. & Damm, A. (2022): Satellite data reveal differential responses of Swiss forests to unprecedented 2018 drought. Global Change Biology, Vol. 28 (9), 2956-2978.

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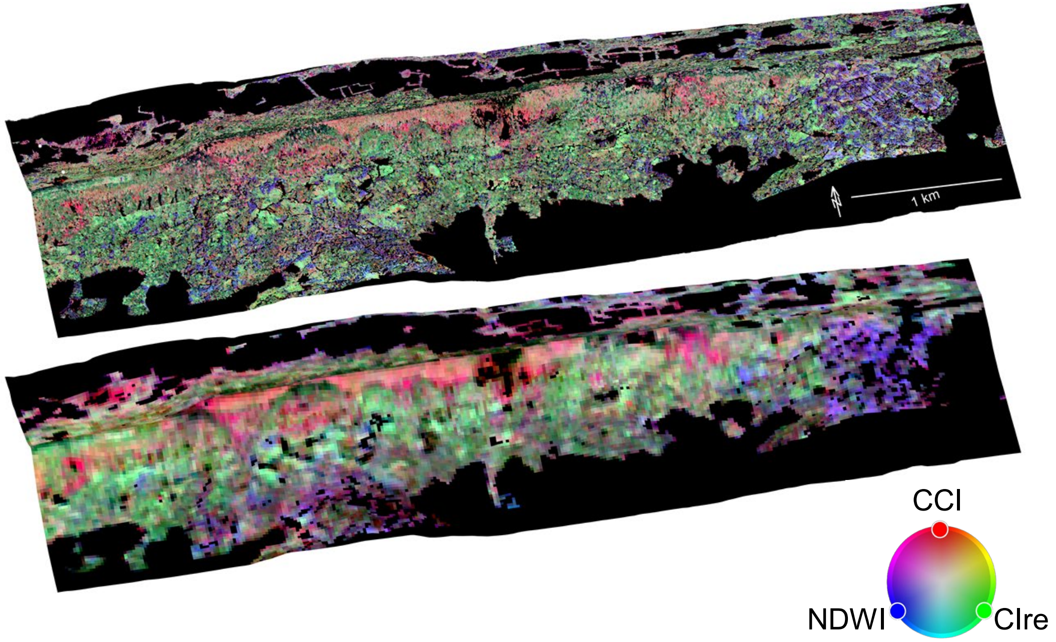

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